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PHYSICAL AND MECHANICAL BEHAVIOUR OF A ROLLER COMPACTED CONCRETE REINFORCED WITH POLYPROPYLENE FIBER

A. Benouadah, M. Beddar, and A. Meddah

LMMS, Département of Civil engineering, University Mohamed Boudiaf - M'sila, Algeria

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ABSTRACT

In order to study the behaviour of a roller compacted concrete (RCC) reinforced with polypropylene fiber, six types of RCC were made with different content of fibers (0, 0.5, 1, 1.5, 2 and 2.5 Kg/m³). The physical parameters are the density, the workability, the shrinkage and the water absorption. For the mechanical parameters; the performances such as the compressive strength and the tensile strength (3 point bending and splitting) has been studied. The results show that the RCC reinforced with fibers present the better performances in terms of strength and physical behaviour. The results obtained show the positive effect of the polypropylene fiber addition on the mechanical strength, which increases about 23% for the mixture with 1 Kg/m³. For the physical properties, there is a decrease in the density and workability and an improvement in the water absorption proportional with the addition of polypropylene fiber. In addition, we conclude the positive effect of polypropylene fiber on the kinetics and development of the shrinkage. In this study, the best physical and mechanical performance was being observed in the mixture with 1 Kg/m³ of polypropylene.

Keywords: Roller compacted concrete, polypropylene fiber, workability, mechanical strength, shrinkage.

Author Correspondence, e-mail: abdelatif.benouadah@yahoo.fr

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1. INTRODUCTION

The field of transport infrastructure is important for economic and socioeconomic development regional, national and international level. The principal element of the transport infrastructure of surface is the solid paving stone, which can be built in order to be soft or rigid. Both construction methods present several advantages and inconvenient in term of traffic loads transferred to the platform [1]. Rigid pavements are made with Portland cement concrete while soft pavements are with asphalt concrete. Although soft pavements are preferred nowadays to the rigid pavements, the researchers continued to evaluate the advantages and the inconvenient of these pavements. The literature tells us that the rigid road built primarily with compacted concrete have a service life longer than asphalt pavements [2]. The use of concrete for the construction of coverings; is now very widespread in the world. The principle of maxing and placing this concrete is very simple; because after determining the amount of water required for mixing: using the principles of geotechnics, it is implemented through a finisher and compacted using roller compactor conventionally used in the production of asphalt. The roller compacted concrete (RCC) thus called because of that installation, offers high resistances and good durability with a speed installation comparable with the asphalt [3].

The use of polypropylene fiber is a useful and economic method in order to improve the characteristics of different concretes. The researchers indicated that the use of this fiber can improve tenacity [4], the bonding strength [5], the impact resistance [6], the tensile strength long-term [7], the behaviour with chipping [8], resistance to abrasion-erosion [9,10], the fire resistance [11,12], the plastic shrinkage [13] and the propagation of the cracks [14]. Several research mentions the advantages and the very broad field of application of the polypropylene fiber, but few research studying the behaviour of these fibers on the special concretes such as RCC. This study aims to understand the physical and mechanical behaviour of a RCC reinforced with polypropylene fiber at fresh and hardened state.

1.1 Materials and Tests

The cement used in this study is a Portland cement composes CEM II 42.5 N manufactured by the Lafarge cement factory located in Algeria according to Standard NF P15-301 [26]. The

mineralogical composition is presented in the table 1:

Table 1. Mineralogical composition of cement

Components	Value (%)
C3S	64
C2S	18
C3A	8
C4AF	10

The RCC is composed of more than 85% of weight aggregates, for this reason three different fraction (3/8, 8/16 and 16/20) were chosen. The physical and mechanical characteristics of the aggregates are grouped in table 2, the particle size of the gravels and sands are presented in fig 1.

Table 2. Characteristics off different aggregates

Materials	Types	Density Kg/m ³	Los angeles %	Fineness modulus	Sand equivalent %
Sand	dune	2670	/	2.06	80.36
	Crushed	2530	/	3.24	94.08
Gravel	3/8	2600	25.00	/	/
	8/15	2660	13.70	/	/
	15/20	2530	11.25	/	/

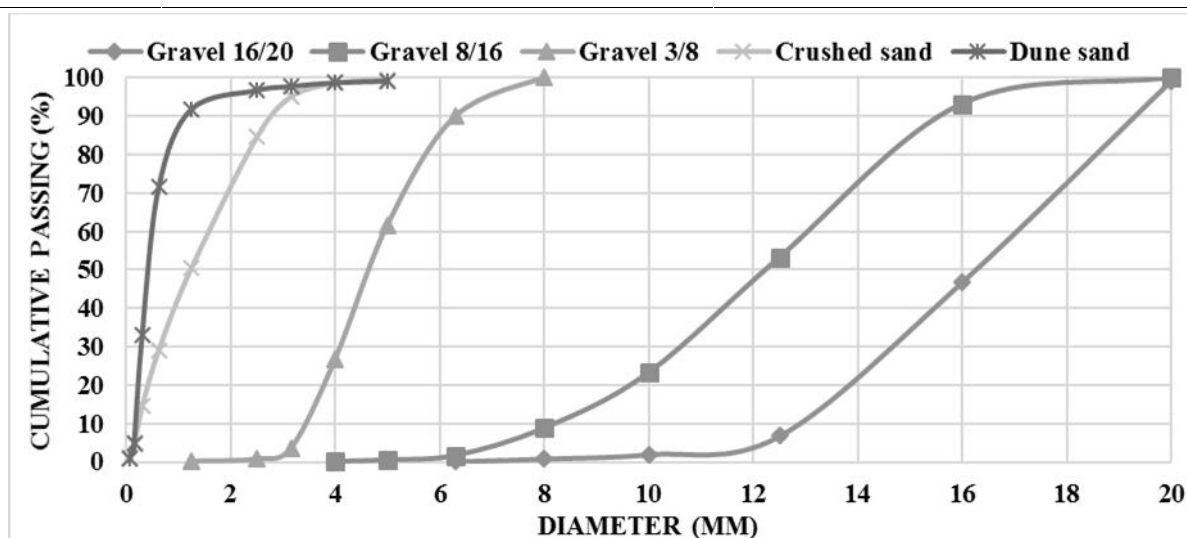


Fig.1. Sieve size of the aggregates

The fibers used in this study in order to reinforce the roller compacted concrete are polypropylene (PP) fibers of the monofilaments types that are available in the TEKNACHEM company located in Algeria. The different characteristics of these fibers are presented in table 3.

Table 3. Characteristics off polypropylene fibers

Characteristics	Size
Length	12 mm
Diameter	28 microns
Density (20°C)	0.8 to 1.00 g/cm ³
Degree of fusion	160 to 170°C

In order to perform this study and to understand the physical and mechanical behaviour of the RCC reinforced with polypropylene fibers, six various mixtures were made with different content of PP fibers (0, 0.5, 1, 1.5, 2 and 2.5 Kg/m³) according to Banthia et al [15]. The formulation used to make the mixture based on geotechnical principles [16, 17]. Table 4 shows the designation and proportions of the various RCC.

Table 4. Composition of different mixtures

Mixture	Gravel (kg/m ³)			Sand (kg/m ³)		Cement (kg/m ³)	Water (kg/m ³)	Fiber (Kg/m ³)
	3/8	8/16	16/20	Dune	Crushed			
RCC0	426.61	433.48	311.60	655.11	311.61	299.38	114.405	0
RCC0.5	426.61	433.48	311.60	655.11	311.61	299.38	114.405	0.5
RCC1	426.61	433.48	311.60	655.11	311.61	299.38	114.405	1.0
RCC1.5	426.61	433.48	311.60	655.11	311.61	299.38	114.405	1.5
RCC2	426.61	433.48	311.60	655.11	311.61	299.38	114.405	2.0
RCC2.5	426.61	433.48	311.60	655.11	311.61	299.38	114.405	2.5

The density in a fresh state and the manoeuvrability of the RCC were measured in accordance with the standard ASTM C1170/C1170M-08 [18]. For the compressive strength, specimens of 100 × 100 × 100 mm were made according to standard ASTM C39/C39M-11a [19] to see the development of strength at 7, 14 and 28 days. For measured the free shrinkage, prismatic

samples are necessary according to the standard ASTM C 157/C 157M – 03 [20].

2. RESULTS AND DISCUSSION

2.1. Fresh state

2.1.1. Physical properties

In this part, the density and the compaction time (VEBE) were studied. The results obtained show a reduction in the density of the concrete with the addition of polypropylene fiber, which is explained by the weak density of the fiber that influence the total density of the concrete. For the time of compaction measured with VEBE test, we can see an increase proportional with the addition of polypropylene fiber what confirms the negative effect of PP fiber on the workability of the concrete [21]. The reduction in workability with addition of PP fiber can be explained by the rate of absorption of the fiber, which is probably due to the creation of a fiber network that interferes with water circulation and makes the concrete drier.

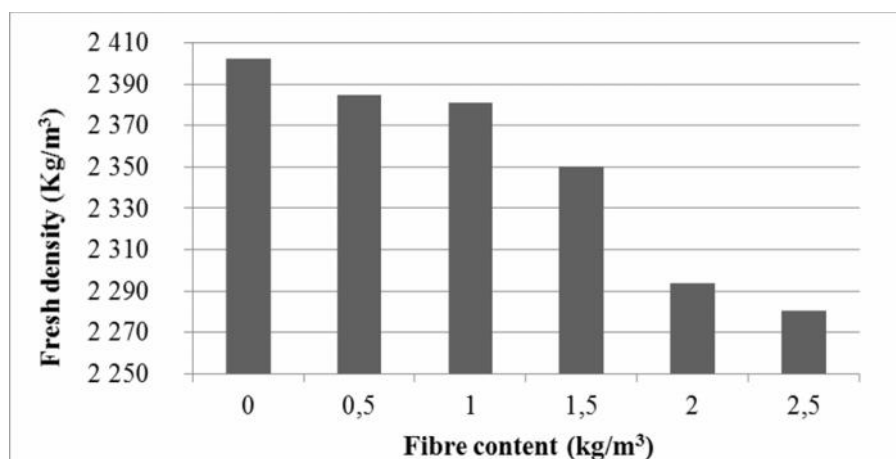


Fig.2. Variation of the density in a fresh state of the various types of RCC

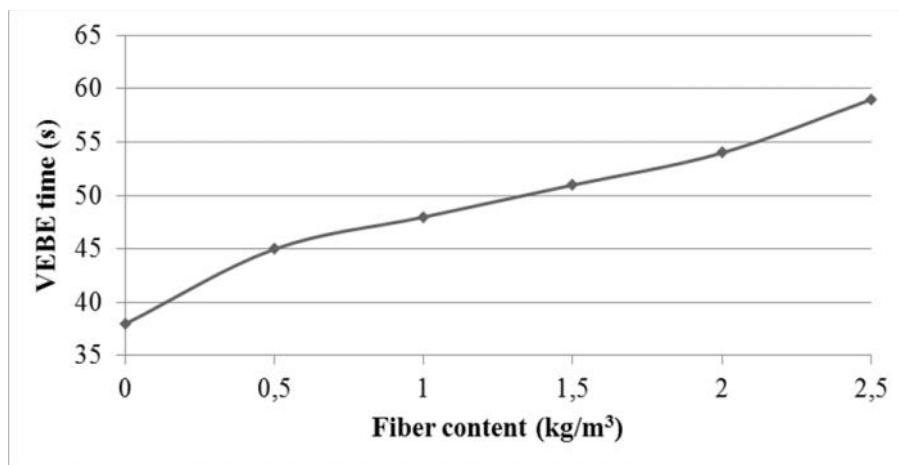


Fig.3. Variation of the workability according to VEBE time of the different types of RCC

2.2. Hardened state

2.2.1. Mechanical properties

In a hardened state, the roller compacted concrete counts two principal parameters, which are the compressive strength and the tensile strength (three-point bending and splitting).

For the compressive strength, we can see from the fig 4 that the effect of polypropylene fiber is beneficial for the 0.5 and 1 Kg per m³ concrete [22], Topçu and Canbaz [23] showed that the fibers could reduce the formation and the development of the cracks, and thus lead to the increase in compressive strength. Beyond 1 Kg per m³, the loss in resistance is noted. This reduction is due to a fiber excess in the mixture, which causes reduction of strength.

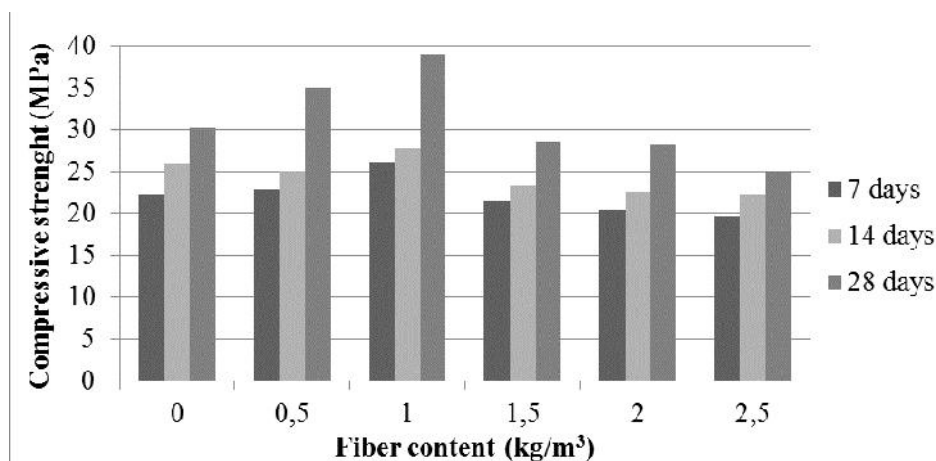


Fig.4. Variation of the compressive strength of various types of RCC at 7, 14 and 28 days

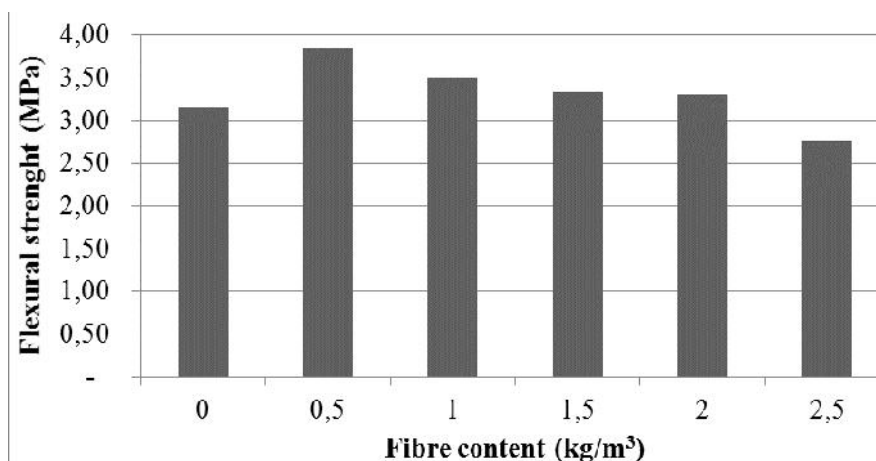


Fig.5. Variation in the tensile strength by bending of the various types of RCC

According to fig 6, which shows the variation of the tensile strength by splitting of the various types of RCC; we can see that the use of polypropylene fiber in RCC with 0.5, 1, 1.5 and 2 Kg/m³ has a positive effect on the tensile strength by splitting. An increase with 32% from the RCC2 compared to the RCC0 can be observed.

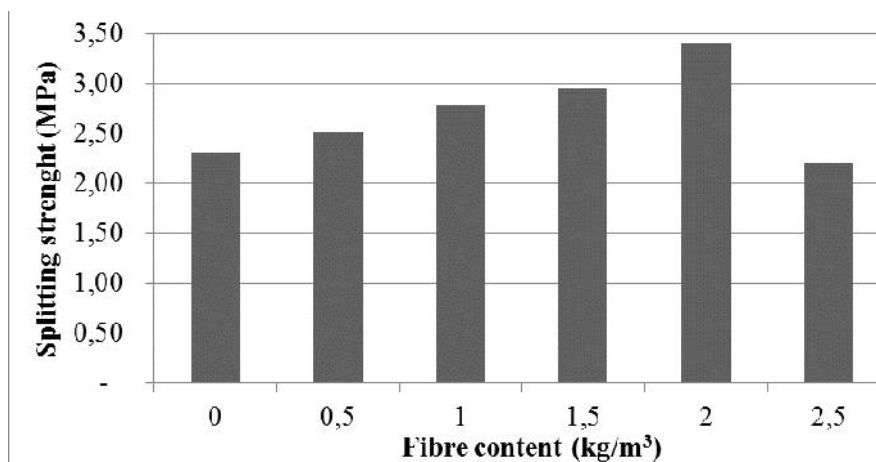


Fig.6. Variation of the tensile strength by splitting of the various types of RCC

Furthermore, a decrease in the tensile strength by splitting was observed for RCC2.5 with 5% compared to RCC0, which is due to an excess of the fiber proportioning (exceeded optimal quantity).

S. Kakooei et al. [24] reported that the increase in the mechanical strength in the concretes reinforced with polypropylene fiber is due to the provision of the fiber, which is in width compared to the cracks creating bridges of connection that make the concrete more resistant.

2.3. Physical properties

2.3.1. Shrinkage

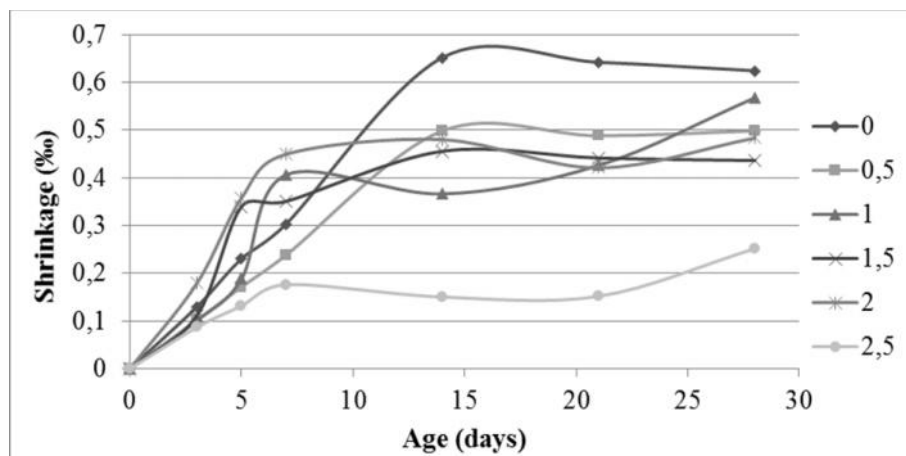


Fig.7. Evolution of the shrinkage of the various types of RCC

Fig 7 show the results of the shrinkage of the various concretes (0, 0.5, 1, 1.5, 2 and 2.5 Kg per m³). We can conclude according to this graph that the shrinkage of the reference mixture without polypropylene fiber is significant compared to the mixture contains polypropylene fibers. RCC2.5 presents a slight shrinkage compared to the other concretes. R.D. Tolêdo Filho et al. [25] indicates that the polypropylene fiber addition reduces the shrinkage considerably which is in coordination with other research.

It is also noted that RCC0 stabilizes at 14 days whereas the mixtures containing polypropylene fiber are stabilized at 7 days from these results it can be concluded that PP fibers have a seam effect on the development of micro-cracks at early ages, which decreases the rate of shrinkage of reinforced concrete with fibers.

The decrease for the shrinkage in mixtures with polypropylene fiber can be explained by the creation of fiber networks, which produce a seaming effect, this allows the RCC with fiber to have a low shrinkage rate.

2.3.2. Absorption

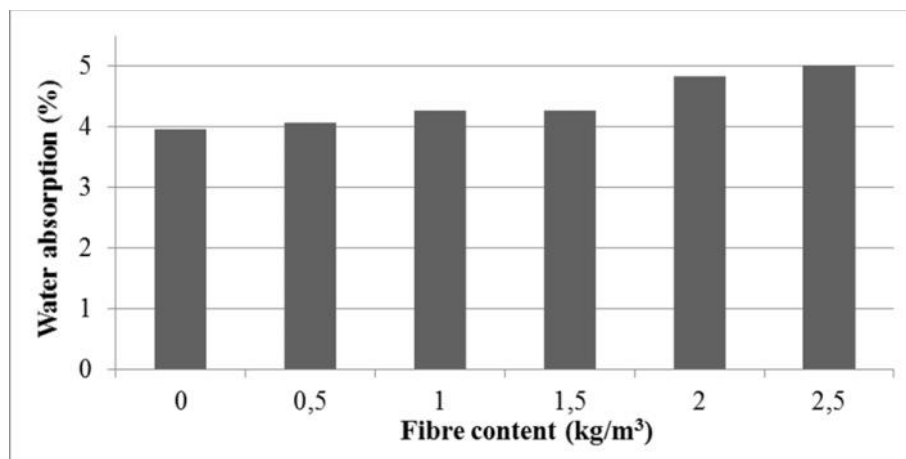


Fig.8. Variation of the degree of absorption of the various concretes

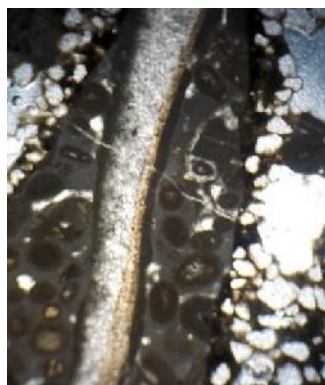
Fig 8 shows water absorption of various concretes. We can see according to the results that the water absorption is proportionally with polypropylene fibers content with (3%, 7%, 8%, 19% and 21%) for (0.5, 1, 1.5, 2 and 2.5 Kg per m³) respectively.

This result proves the negative effect of polypropylene fiber on water absorption especially at (2 and 2.5 Kg per m³).

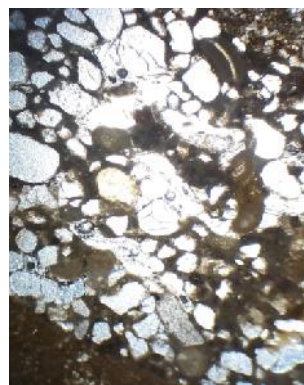
2.4. Visual appearance under optical microscope

In this part, we wanted to see the incorporation of polypropylene fibers on a microscopic scale. For that, we prepared samples of RCC and other of RCC reinforced with PP, then we made them pass from an optical microscopic. The two pictures obtained from the optical microscope represents the RCC without PP and the RCC with PP are presented in fig 9.

We can see from the picture (A) the presence of a fiber that fits perfectly in the cement matrix. The second picture (B) shows RCC without fiber.



(A)



(B)

Fig.9. Microscopic photography: (A) RCC with PP fiber, (B) RCC without PP fiber

3. CONCLUSION

The purpose of this study is principal to understand the behaviour of a RCC reinforced with polypropylene fibers. The conclusions tired from this study are:

The addition of fibers in RCC reduces the density of the concrete, which can be explained by the weak density of the PP fibers.

The workability of the RCC fell with the addition of fibers. This phenomenon is current in the concretes reinforced with fiber; several research found the same thing. The reduction of workability is explained by the rate of absorption of synthetic fibers, which is probably due to the creation of a fiber network that interferes with water circulation.

The incorporation of polypropylene fibers in a roller compacted concrete gave satisfactory results in term of mechanical strength. The PP fibers were located in width compared to the crack what improved the arrow of the concrete.

The behaviour of the RCC fiber against the shrinkage is remarkable. More the content of fiber is high more the shrinkage decreases. We can explain the effect of fibers on the shrinkage by the phenomenon of seam of the cracks, which prevents the development of the free shrinkage.

The water absorption of concretes is clearly indicating that the PP fibers have a detrimental effect on the absorption of the concretes; the reduction of the workability consolidates these results.

The visual aspect of the concretes observed under optical microscope shows the positioning of the polypropylene fibers clearly in the matrix of the roller compacted concrete. It is observed that the cement paste has well wrapped the PP fiber, also we can see a segregation caused probably by the presence of PP fiber.

After studying possible incorporation of polypropylene fibers in a roller compacted concrete, it can be concluded from this study that the incorporation of 1 Kg per m³ gives results conclude at the physical and mechanical properties.

4. ACKNOWLEDGEMENTS

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